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APPLICATION NO. 09/826,118

TITLE OF INVENTION: Wavelet Multi-Resolution Waveforms

INVENTOR: Urbain A. von der Embse

Currently amended CLAIMS

APPLICATION NO. 09/829,118
INVENTION: Wavelet Multi-Resolution Waveforms
INVENTORS: Urbain A. von der Embse

CLAIMS

WHAT IS CLAIMED IS:

Claim 1. (cancelled~~deleted~~)

Claim 2. (cancelled~~deleted~~)

Claim 3. (cancelled~~deleted~~)

Claim 4. (cancelled~~deleted~~)

Claim 5. (cancelled~~deleted~~)

Claim 6. (cancelled~~deleted~~)

Claim 7. (previously presented~~currently amended~~) A least-squares method for generating and applying Wavelet waveforms and filters, said method comprising the steps:

said Wavelet is a digital finite impulse response waveform at baseband in the time domain,

linear phase finite impulse response filter requirements on the passband and stopband performance of the power spectral density are specified by linear quadratic error metrics in the Wavelet,

Wavelet requirements on the deadband for quadrature mirror filter properties required for perfect reconstruction are specified by a linear quadratic error metric in the Wavelet,

Wavelet orthogonality requirements for intersymbol interference and adjacent channel interference are specified by non-linear quadratic error metrics in the Wavelet,

non-linear quadratic error metrics have quadratic coefficients

dependent on the Wavelet,

Wavelet multi-resolution property requires said error metrics to be converted to error metrics in the discrete Fourier transform harmonics of the Wavelet which harmonics are the Wavelet impulse response in the frequency domain,

using a least-squares recursive solution algorithm with quadratic error metrics, which algorithm requires a means to find the Wavelet harmonics that minimize the sum of said linear quadratic error metrics,

said harmonics are used to linearize said non-linear quadratic error metrics,

said least-squares recursive solution algorithm finds the harmonics which minimize the weighted sum of the linear and linearized quadratic error metrics,

said least-squares recursive solution algorithm starts over again by using said harmonics to linearize the non-linear error metrics and to find the corresponding harmonics which minimize the sum of said linear and linearized quadratic error metrics,

said least-squares recursive solution algorithm continues to be repeated until the solution converges to the design harmonics of the Wavelet which is the least-squares error solution, and

said Wavelet impulse responses in the time domain and frequency domain are implemented in communication systems for waveforms and filters.

Claim **8**. (<u>previously presented</u>~~currently amended~~) A second least-squares method_for generating and applying Wavelet waveforms and filters, said method comprising the steps:

linear phase filter requirements on the passband and stopband

performance of the power spectral density are specified by linear quadratic error metrics in the Wavelet impulse response in the time domain,

using a least-squares recursive solution algorithm with norm-squared error metrics, which algorithm requires a initialization Wavelet and a means to find the Wavelet harmonics which minimize the sum of said linear norm-squared error metrics,

said initialization Wavelet is the optimum Wavelet that minimizes the weighted sum of said linear quadratic error metrics which optimum Wavelet is found using an eigenvalue, Remez-Exchange, or other optimization algorithm,

said linear quadratic error metrics are transformed into linear norm-squared error metrics in the Wavelet,

Wavelet requirements on the deadband for quadrature mirror filter properties required for perfect reconstruction are specified by a linear norm-squared error metric in the Wavelet,

Wavelet orthogonality requirements for intersymbol interference and adjacent channel interference are specified by non-linear norm-squared error metrics in the Wavelet,

non-linear norm-squared error metrics have norm coefficients dependent on the Wavelet,

Wavelet multi-resolution property requires said error metrics to be converted to error metrics in the discrete Fourier transform harmonics of the Wavelet which harmonics are the Wavelet impulse response in the frequency domain,

using said least-squares recursive solution algorithm to find the harmonics that minimize the weighted sum of said least-squares linear and non-linear norm-squared error metrics, which harmonics are the design harmonics of the Wavelet least-squares error solution, and

said Wavelet impulse responses in the time domain and frequency domain are implemented in communication systems for waveforms and filters.

Claim **9.** (~~deleted~~cancelled)

Claim **10.** (currently amended) A further method of applying ~~Wherein applications of the~~ Wavelet waveforms and filters ~~in~~ of claims 7 or 8, comprising:

inverse Discrete Fourier Transform (DFT) defines ~~the~~ a mother Wavelet digital finite impulse response waveform $\psi(n)$ as a a function of the ~~frequency domain~~ design harmonics ψ_{k_0} ~~in equation (11)~~ in accordance with:

$$\psi(n) = (1/N') \sum_{k_0} \psi_{k_0} W_{N'}^{k_o n}$$

wherein:

$\psi(n)$ = mother Wavelet time response for index n;

ψ_{k_0} = mother Wavelet frequency response harmonic for frequency index k_o;

$\sum_{n}$ = summation over time index n;

$W_{N'}^{k_o n}$ = $e^{i2\pi kn/N'}$

= inverse DFT phase rotation for index n length N′ wherein i=√(-1~~)T~~);

wherein mother Wavelet refers to a Wavelet at baseband which is used to generate other Wavelets;

nulti-resolution Wavelets ($\psi_{p,q,r}(n) = 2^{-p/2}\psi(2^{-p}n - qM)\,e^{i2\pi f_c(p,r)nT}$) ~~forscale and translation parameters~~ are defined as a function of the design harmonics of the mother Wavelet $\psi(n)$ ~~in equation~~

~~(18)~~in addition to multi-resolution scale parameters p,q,r according to:

$$\psi_{p,q,r}(n) = (2^{-p/2} / N') \sum_{k_0} \psi_{k_0} W_{N'}^{k_0(n(p)-qM)} e^{i2\pi f_c(p,r)n(p)2^p T}$$

wherein:

p = multi-resolution traditional Wavelet scale parameter;

q = multi-resolution traditional Wavelet translation parameter;

r = frequency index is a generalization of frequency index k_o and identifies the center frequency of the multi-resolution Wavelet at the scale p;

$\psi_{p,q,r}(n)$ = multi-resolution Wavelet time response for scale p, translation q, frequency index r, at time index n;

M = sampling interval for Wavelet ψ;

$f_c(p,r)$ = center frequency of the frequency translated mother Wavelet ψ, at scale p and frequency index r;

T = time interval for digital sampling index n;

~~mother Wavelet design harmonics are defined in terms of the Wavelet impulse time response digital samples in equation (20),~~

~~Wavelet design in the frequency domain allows a mother Wavelet to be re-scaled for application to multi-channel polyphase filter banks by implementing equations (11),(18),(20) which derive a multi-resolution Wavelet from a mother Wavelet by using the design harmonics of the mother Wavelet and the multi-scale parameters of the Wavelet impulse response for said application,~~

~~wherein mother Wavelet refers to a Wavelet at baseband which is used to generate other Wavelets,~~

forming a multi-channel polyphase filter bank using a multi-resolution Wavelet based on the design harmonics of the mother Wavelet and selection of multi-scale parameters including one or more traditional Wavelet parameters plus frequency, spacing, and length wherein:

~~wherein multi-scale parameters are the traditional scale, translation, timing parameters, plus frequency, spacing, and length parameters of this invention, and wherein scale parameter scales time interval between samples, sub-sampling, over-sampling, and translation interval between Wavelets,~~

~~translation parameter is the timing offset of the Wavelets in units of the spacing parameter,~~

~~timing parameter is the digital sampling interval,~~

frequency parameter is a frequency offset which translates the Wavelet in frequency~~,~~ ;

spacing parameter is ~~the~~ a number of digital samples for Wavelet spacing which is equal to ~~the~~ a number of channels in a polyphase filter bank with a Nyquist sampling rate;~~,~~

length parameter specifies ~~the~~ a length of the Wavelet in the sampling domain~~,~~ ; and

said multi-~~scale~~ resolution parameters and the mother Wavelet design harmonics generate the multi-resolution Wavelet for the multi-channel polyphase filter bank incorporated in a communications system.

Claim **11.** (cancelled~~deleted~~)

Claim **12.** (currently amended) Wherein the method of claim 10, ~~properties of Wavelet waveforms and filters in claims 7 or 8,~~ further comprising:

~~Discrete Fourier Transform (DFT) defines the mother Wavelte interms of the frequency domain design harmonics in equation (11),~~

~~mother Wavelets for scale and translation parameters are defined of the design harmonics in equation (18),~~

~~mother Wavelet design harmonics are defined in terms of the Wavelet impulse time response digital samples in equation (20),~~

~~said Wavelets are multi-resolution Wavelets which enable a single Wavelet design at baseband to be used to generate Wavelets for multi-resolution applications by implementing equations (11),(18)(20) and using the Wavelet design harmonics and the multi-scale parameters for the multi-resolution Wavelet applications,~~

selecting the design harmonics and multi-resolution parameters so that ~~said~~ the Wavelet is designed for a communications waveform with no excess bandwidth,

varying the sampling rate in the frequency domain to enables~~said~~ the multi-resolution Wavelets ~~are designed~~ to behave like an accordion in that at different scales the Wavelet is a stretched or compressed version of the mother Wavelet,

~~said~~ modifying the constraints on the error metrics to enable the multi-resolution Wavelets to be designed ~~linear waveform and filter least-squares design methods are modified to design non-linear Wavelet waveforms~~ for other applications including bandwidth efficient modulation and synthetic aperture radar, and

other optimization algorithms ~~exist~~ for generating ~~finding~~ said Wavelets.